Design of a horizontally deflecting Quadruple Crystal Monochromator (QCM) for I13 at Diamond

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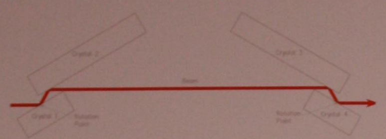
Introduction

The long I13 beamline at Diamond features two branches (Imaging and Coherence) with the experimental stations around 230m from the source. For the Coherence branch we opted to develop and build our own 4 bounce Quadruple Crystal Monochromator (QCM).



A channel cut monochromator potentially offers greater stability over a typical DCM as much better parallelism is maintained between faces of the 1st and 2nd crystals.

However a big disadvantage is that the beam offset is variable with energy. An alternative solution is to use two channel cuts in a four bounce geometry which provides a fixed offset.

We were unconvinced that sufficient flatness and quality of finish could be produced in the faces of the crystal channel cuts for our application. Therefore we chose a "pseudo" channel cut design where each crystal could be finished to a high standard and mounted individually.

The 1st & 4th crystals are rigidly fixed, whilst the 2nd & 3rd crystal feature individual pitch and roll corrections via flexure pivots and piezo devices. For the coherence branch, the divergence in the horizontal direction is smaller than the vertical, therefore we adopted a sideways bounce geometry which also potentially offers better stability as the crystal cage can be more directly supported from underneath.

Key Design Specification

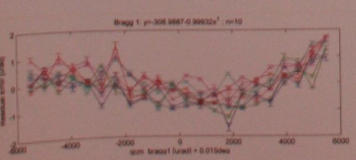
The monochromator was to be initially installed in the External building at around 215m from the source - in this location water cooling is sufficient, though in future if the QCM proves exceptionally stable it may be moved much closer to the source (to further optimise coherent flux).
Here cryo cooling cooling may be required therefore it needed all the design features of a cryogenically cooled monochromator.

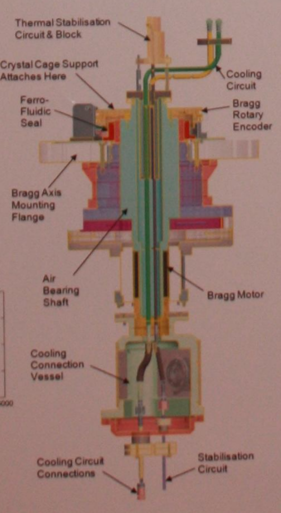
- Energy Range 4keV – 35keV
- Two crystal sets :-
  Si(111) for 4keV-23keV *(29°- 5°)* & Si(311) for 7.5keV-35keV *(29 - 6.6°)*
- Independent lateral translations for single spindle operation.
- Vertical height adjustment for crystal set selection.
- Removal of both crystal cages from beam for straight through (Pink Beam use)
- Fixed sample position for all beam scenarios.

Bragg Axis Drives

The air bearing spindles are based on an original Daresbury design and subsequent developments made at Diamond on the I20 beamline 4 Bounce Monochromator.

- Brushless DC motor driven.
- In-vacuum rotary encoder providing <0.05μrad resolution.
- Ferrofluidic seal.
- Coolant circuits pass through main shaft.
- Parasitic roll effect not measurable over +/- 6mrad scans
- Closed loop repeatabiltiy within 1-2μrad over +/-6mrad scans





Section Thro' Bragg Axis

Crystal Cages

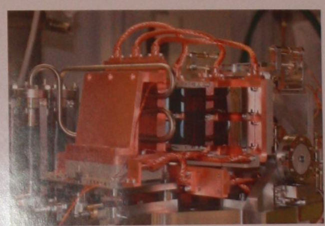
Upstream crystal cage 1 is shown below (crystal cage 2 is the mirror image).
The 1st & 4th crystals are rigidly mounted with manual pre-alignments only.
Similar to a previous crystal cage development carried out by DLS for the I18 beamline at Diamond, the 2nd & 3rd crystals are mounted using cross flexures and piezo type drives for coarse and fine adjustment of pitch & roll.
Rotary encoders are mounted directly on axis for direct positional readout.

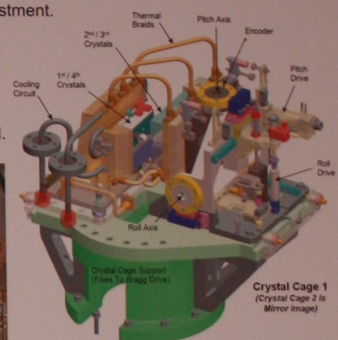
Both 1st & 4th crystals are bottom cooled and mounted on directly cooled copper mounts via separate cooling circuits whilst the 2nd & 3rd crystals are bottom cooled by braids attached to the primary cooling circuits.

For future cryo cooled use, a thermal stabilization water circuit is included with braid connections to key parts of the crystal cage.

Mechanical tests with a high precision autocollimator showed no measurable parasitic roll over +/-30μrad fine pitch adjustment.

2nd & 3rd Crystal Pitch / Roll Adjustments:-
- Coarse Range > +/-5°
- Fine Range +/-240μrad
- Encoder resolution <0.1μrad
- <10nrad under closed loop piezo control.

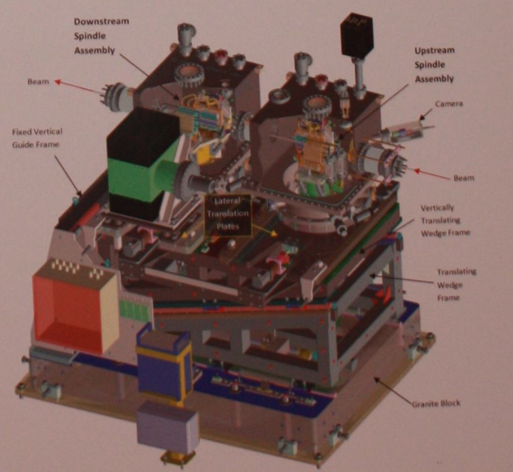




Upstream Crystal Cage 1

Vacuum System Support System

Each Axis is housed in a separate vacuum chamber connected via bellows.
Operating vacuum achieved so far <5x10^{-8} mbar
Sand filled welded frame assembly based on a translating wedge to achieve the +/-25mm vertical translation.
Individual lateral translations provide +/-8mm motion across beam.



QCM Assembly

Summary

The QCM has been in operation on the Coherence beamline since March 2012 during a very busy period of installation & commissioning of both branches. Initial mechanical tests made during commissioning show similar performance to the crystal cage developed successfully for I18 at Diamond
The QCM has now been used in all 3 beam scenarios (4 bounce, 2 bounce and straight thro' pink beam) and found to perform well.
More comprehensive performance data with beam is expected over the coming months.

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For more information please visit www.diamond.ac.uk or contact Andy Peach at Andrew.Peach@diamond.ac.uk